Measurement of excitation functions relevant to the production of the positron emitter ^{90}Nb via the ^{90}Zr(p,n)-reaction

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Introduction: The radioisotope ^{90}Nb decays with a high positron branching of 51% and a relatively low β^+-energy of E_{mean} = 0.66 MeV and E_{max} = 1.5 MeV. Its half-life of 14.6 h makes it especially promising for quantitative investigation of biological processes with slow distribution kinetics using positron emission tomography. ^{90}Nb was originally identified via (p,n) and (d,2n) reactions on ^{90}Zr. High-purity ^{90}Nb was first obtained via the decay of ^{90}Mo [1]. For the production of ^{90}Nb today, several nuclear reactions seem to be reasonable: the (p,n)- or (d,2n)-processes on ^{90}Zr and the (^{3}He,2n)- or (α,3n)-reactions on natural yttrium. A medium-sized cyclotron would be able to produce ^{90}Nb via the (p,n)-, (d,2n)- or the (^{3}He,2n)-process.

In fact even a small-sized (≤ 16 MeV proton energy) cyclotron should lead to sufficient quantities of the radioisotope via the (p,n)-reaction. A few studies have shown that the (d,2n)-reaction requires a deuteron energy of about 16 MeV [2-4], the (^{3}He,2n)-process a ^{3}He-energy of ≥ 30 MeV and the (α,3n)-reaction an α-particle energy of ≥ 45 MeV [5]. Furthermore, the systematics of (^{3}He,2n)- and (p,n)-reactions suggest that the production yield of ^{90}Nb should be higher in the latter process.

With the common availability of dedicated cyclotrons for producing short-lived β^+-emitters, the (p,n) reaction represents an advantageous route for production of ^{90}Nb. Some cross section data on the ^{nat}Zr(p,xn)-reactions using thick target irradiations with high initial proton energy have already been reported in the literature [6,7]. However, those experiments were not designed to determinate cross sections in the low energy region relevant to the production of ^{90}Nb, i.e. at E_p < 20 MeV. The data display large uncertainties because large foil-stacks with high incident proton energies (for example, E_p = 70→10 MeV) were used.

Experiments: To optimise its production, the excitation functions of ^{90}Zr(p,xn)-processes were studied over the most relevant proton energy range of 7.5 to 19 MeV via the stacked-foil technique using both ^{nat}Zr and 99.22% enriched $^{90}ZrO_2$ as targets. Thick target yields of ^{90}Nb were calculated from the measured excitation functions and verified experimentally.

Results: The optimum energy range for the production of ^{90}Nb via the ^{90}Zr(p,xn)-process was found to be E_p=17→7 MeV, with a yield of 600 MBq ^{90}Nb/µA·h. The yield and radionuclidic purity of ^{90}Nb over the energy range of E_p = 17.6→8.1 MeV were determined experimentally using ^{nat}Zr. At 4 h after EOB the yield of ^{90}Nb was found to be 290 MBq/µA·h and its purity ≥ 95%.

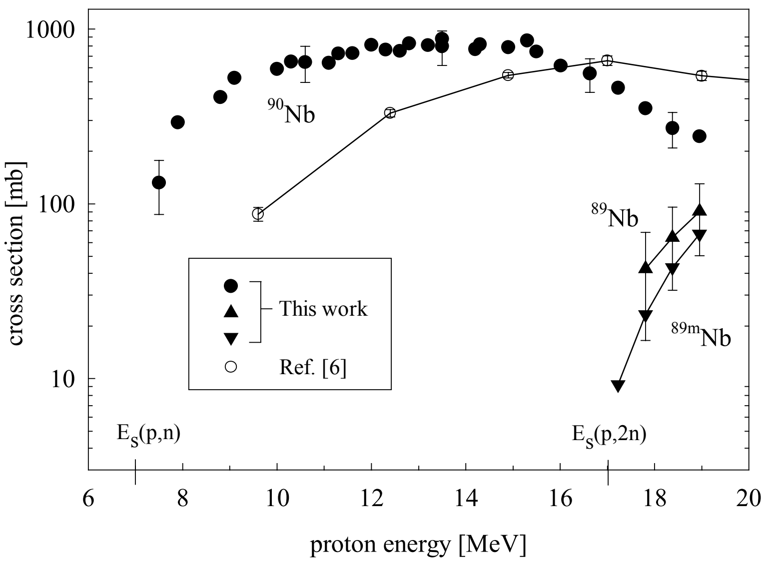

Fig. 1. Excitation functions of ^{90}Zr(p,xn)-processes leading to the formation of ^{90}Nb, ^{89m}Nb and ^{89}Nb (the literature data [6] for the production of ^{90}Nb are also given). The values for ^{90}Nb describe the cumulative formation cross section. Typical error bars in different energy regions are also given.

The results of the cross section measurements indicate that ^{90}Nb can be produced with sufficient batch activities of the order of 10 GBq and in high isotopic purity by means of the (p,n)-process on highly enriched ^{90}Zr at a small cyclotron providing maximum proton energies of about 16 MeV. Sufficient quantities of ^{90}Nb can also be produced using ^{nat}Zr as target material, the radionuclidic purity, however, would then be 95%.

References

1. Butement, F.D.S., Qaim, S.M.: J. Inorg. Nucl. Chem. 26, 1481 (1964).
2. Mercader, R. C., Caracoche, M. C., Mocoroa, A. B.: Z. Physik 255, 103 (1972).
3. Wasilevsky, C., Dos Santos, F., Herreros Usher, O., Nassiff, S. J.: Radiochem. Radioanal. Lett. 32, 127 (1978).
4. Gonchar, A. V., Kondratev, S. N., Lobach, Yu. N., Nevskii, S. V., Skylyarenko, V. D., Tokarevskii, V. V.: Atomnaja Energija 75, 205 (1993).
5. Smend, F., Weirauch, W., Schmidt-Ott, W.-D., Flammersfeld, A.: Z. Physik 207, 28 (1967).
6. Kondratev, S. N., Kuzmenko, V. A., Lobach, Yu. N., Prokopenko, V. S., Sklyarenko, V. D., Tokarevskii, V. V.: Atomnaja Energija 71, 325 (1991).